

Implementing A2LA's New Budget Requirements For Electrical and RF Uncertainties in Fluke MET/CAL[®] Procedures

Speaker: Michael L. Schwartz
Cal Lab Solutions
PO Box 111113, Aurora CO 80042 US
T: 303-317-6670 | F: 303-317-5295
Email: MSchwartz@CalLabSolutions.com
Email: KHaynes@ElectroRent.com

Authors: Michael L. Schwartz, Cal Lab Solutions
Karl Haynes, Electro Rent Corporation

Learning Objectives: The attendee will be familiarized with A2LA's new minimum required contributors for Electrical and RF & Microwave uncertainty budgets that support the Calibration and Measurement Capabilities (CMC) on the scope of accreditation. Attendees will also learn methods of retrofitting MET/CAL[®] procedures to work within the new standards. Attendees could take the concepts and methods presented herein and apply them to their laboratory processes resulting in a more uniform uncertainty analysis throughout the industry.

Abstract: In April of 2009, the A2LA Measurement Advisory Committee adopted the minimum required contributors that must be included in your Electrical and RF & Microwave uncertainty budgets that support the Calibration and Measurement Capabilities (CMC) on the scope of accreditation. Their June 2009 newsletter explains the new requirements that went into effect for organizations with a renewal date of May 31st, 2010 or greater. For many labs, software is an integral part of their calibration process as well as the primary tool used to calculate uncertainties. So, it is crucial that existing calibration procedures be updated to meet this new requirement, as the basic procedure steps do not include specific lab and traceability contributors. In this paper, we explain our interpretation of the requirements and suggest a standardized method to retrofit them to existing MET/CAL[®] procedures. Additionally, we describe enabling guard bands and checks for <2% false accept risk through MET/CAL's[®] Crystal Reports[®]. Our presentation will demonstrate using a high voltage source calibration procedure using MET/CAL[®] code.

1. Introduction

In April 2009, the A2LA Measurement Advisory [technical] Committee (MAC) reached consensus and adopted a new set of minimum requirements that must be included for all electrical and RF & Microwave uncertainty budgets that support the Calibration and Measurement Capabilities (CMC) on the scope of accreditation. As of May 31st, 2010, these new requirements are in effect; consequently, uncertainty budgets will be checked for these minimum requirements. A draft ILAC policy document suggests CMC and lower accuracy uncertainty budgets include the same influences.

For many labs, meeting these requirements will only require a closer review and some minor updates to their uncertainty budgets. For calibration labs running automated calibration software, they will have to ensure their automated software packages are able to meet these new requirements. We suggest an implementation for the MET/CAL[®] calibration software procedures.

2. A2LA's Newly Adopted Requirements

In the June 2009 newsletter, A2LA specifically outlines a minimum of eight items [1] that must be addressed with two additional items where additional contributors can be included.

Each of these items, along with their specific requirements, are listed in the table (Table 1) below:

Table 1. Newly adopted requirements.

Item#	Name	Requirement	Comments
1-A	Repeatability	Must have	Try getting 10 or more measurements so you have at least 9 DoF.
2-A	Reproducibility	If possible	For example, long term data.
3-A	Stability/Drift	If possible	See item B6.
4-A	Others	If possible	--
5-B	Reference value from the Accredited, Traceable Certificate	Must have	With this value listed, you have proof traceability.
6-B	Absolute Specification for calibration interval	Must have to check if item B5 is less than item B6	Also, if you have long term stability for this parameter for this range, you can set the multiplier/divisor to 0.
7-B	Resolutions of standards used	Always list	This is usually small to the rest, but there are exceptions.
8-B	Resolution of UUT	Always list	This is usually small to the rest, but there are exceptions.
9-B	Environmental effects	Must have, there can be multiple lines for it.	This is usually small to the rest, but there are exceptions.
10-B	Any other entries that might be helpful for others		
For more details, visit A2LA's web site to download the June 2009 newsletter (http://www.a2la.org/newsletters/June_2009_Newsletter.pdf).			

These uncertainty influence components are divided into both Type-A & Type-B uncertainties. For the purposes of this paper, we will address each using the A2LA number followed by the type of uncertainty as listed in the above table.

Items 1-A through 4-A are all items related to the Type-A uncertainties. Repeatability (item 1-A) is listed as a hard requirement which must be included in your uncertainty budgets, whereas Reproducibility (item 2-A) and Stability and Drift (item 3-A) are optional. Item 4-A is a place

holder for any additional Type-A uncertainties that can impact the measurement. These are again optional and can vary from discipline to discipline.

Items 5-B through 10-B are all Type-B uncertainties. Reference Value (item 5-B) is a hard requirement and shows proof of traceability (measurement and uncertainty). The Absolute Specification (item 6-B) must also be included, but can be set to zero if stability and drift data is available. Resolution of Standard and UUT (Items 7-B & 8-B) are also required; these are typically a rectangular distribution and have to be converted to a gaussian distribution. Environmental Effects (item 9-B) also must be taken into account. Finally, (item 10-B) is a place holder for any additional Type-B uncertainties that can impact the measurement.

3. Meeting These Requirements In Software

The focus of this paper is to publicize the new requirements and provide a real world implementation in a relatively simple industrial calibration procedure. In these examples, we chose to use Fluke's MET/CAL[®] platform because of its penetration in electrical and RF & microwave calibration areas. The underlying concepts detailed in this paper should apply to other automated test platforms.

3.1 MET/CAL Overview

The MET/CAL[®] calibration platform was originally developed as an automated test solution used on the 1720 series controllers. Since then, MET/CAL[®] has evolved into a high level scripting language used in calibration labs around the world. Over the years, it has shifted with the times moving from Microsoft DOS to Windows, and from a file based system to a database / calibration tracking application [2].

Today, many calibration labs use MET/CAL[®] in their electrical labs to calibrate meters and oscilloscopes. Procedures are commonly developed to control RS232 & IEEE488 hardware over the communication bus, saving both time and money. With built-in uncertainty calculation, accuracy files, and a powerful reporting package MET/CAL[®] has greatly simplified the process of reporting your test accuracy ratio (TAR) and uncertainty of measurement.

3.2 MET/CAL Out of the Box

MET/CAL[®] uses script commands called FSC, or Function Select Codes [3]. These FSC are high level programming codes used to control instruments, make calculations, display instructions or pictures to the operator, control program flow and evaluate Pass or Fail for each test point.

These FSC are programmed and compiled into a procedure and executed when the program is run.

There are several FSC used in MET/CAL[®] which are fully explained in the 1000+ page reference manual. For the purposes of this paper, we only focus on those that will help us correctly calculate the measurement uncertainty.

ACC: Used to set the specifications of the standard(s) being used (item 6-B). Typically, it is filled out with the manufacturer's published specifications for a given period of time and associated confidence level. Note: When using instrument specific FSC (i.e. 5500, 5700), the accuracy information from MET/CAL[®] is included in the associated .acc files.

TARGET: Used to control the program flow while executing. If the procedure is running in statistics mode, collecting measurement repeatability statistics (item 1-A), a TARGET -M must be placed before the measurement is made. With each repeat of the measurement, MET/CAL[®] will calculate the repeatability uncertainties repeating the measurement x number of times and calculating the standard deviation (see VSET NMEAS).

VSET & TSET: Used to set MET/CAL[®] operational variables. The VSET command set the variable globally while the TSET sets the variable for that test point only.

VSET UUT_RES: Sets the resolution of the UUT in MET/CAL[®] (item 8-B) Note this is optionally used; when analysis of the variables shows the inferred resolution is not correct, the measurement resolution can be adjusted or the VSET UUT_RES can be used to explicitly state the resolution.

VSET NMEAS: Sets the number of measurements MET/CAL[®] will make when calculating the repeatability uncertainty (item 1-A). (See TARGET.)

VSET CONF: Sets the confidence factor for which the uncertainties are calculated. The value must be set in a sigma value, not as a percentage.

VSET COV_FAC: Sets the Coverage Factor used to calculate the expanded uncertainties. Default values are set to 2.0.

VSET S1: A component of variable U2 Performs $(SDEV / (N ^ 0.5)) * F$, which is an estimate of the sample error of the mean.

VSET S2: A component of variable U2 Performs $(UUT_RES * 0.5) / (3 ^ 0.5)$ which is an estimate of the finite resolution contribution.

VSET U1-10: Sets the specific uncertainty to calculate the total uncertainty of the test. U3 through U10 are not populated by the default MET/CAL[®] configuration.

VSET C1-10: Sets the Sensitivity Coefficients for each one of the uncertainty contributors. By default, these are set to 1.0.

VSET DF1-10: Sets the Degrees of Freedom for each uncertainty element.

VSET MFILE: Outputs the variables and other uncertainty specifics to a file for review or reporting, which can be easily imported into an Excel file for review.

Using these variables, MET/CAL[®] is able to calculate the expanded measurement uncertainties in most procedures. MET/CAL[®] can be easily be configured to collect data and calculate most of the uncertainty contributors set forth in A2LA's minimum requirements. By simply adding VSET commands (NMEAS=10 & CONF = 2.0) and optional TARGET statements, MET/CAL[®] will repeat each measurement and calculate and store the expanded uncertainties at each test point.

However, this alone does not meet the minimum requirements as defined by A2LA. Only items 1-A, 6-B and 8-B have been included in your uncertainty budgets. Additional steps are required to include the additional required items 5-B, 7-B and 9-B. And, if you have the data available, items 2-A and 2-B, as well as 4-A and 10-B, will also need to be addressed.

4. Our Implementation

In our implementation, we demonstrate how to add the remaining uncertainty contributors to your total uncertainty budget. We explain how to store some of these contributors in a local data file so they can be periodically updated. We will also verify that each of the items are set correctly by reviewing the uncertainties output using the VSET MFILE setting.

First, we update our existing procedure verifying the TARGET FSC was being used properly on every test point. This allowed the procedure to take multiple measurements at each test point and calculate the repeatability of the measurement. Then, in the procedure we added the following lines of code to enable the procedure to take 10 measurements:

```
VSET      NMEAS = 10
VSET      CONF = 2.00
```

In order to meet these requirements and minimize the amount of code we had to support, we decided to write a series of drivers. This allowed us to store the uncertainties related to a specific standard in one place, thus minimizing the total support and maintenance required to maintain compliance.

First, we addressed the Reference Value (item 5-B) which required us to store the calibration data from the last calibration in a convenient and easily updated format. We chose to store this data in an INI formatted file since they are easily updated and maintained by novice or expert users. In our driver model, we allowed each of the drivers to have specific knowledge of standards used, the calibration data points and the specific format of the associated .ini file. In addition, each driver was also written to include the Absolute Specifications (item 6-B) or Stability / Drift (item 3-A), as well as Resolution of the standard (item 7-B). We can also include any Environmental effects (item 9-B) in each driver.

4.1 Accuracy Estimate for the Calibration Interval

Normally, the System Accuracy is looked up in a MET/CAL[®] accuracy file. The accuracy file used is typically selected automatically, based on the instrument (the calibration standard) and the calibration interval specified for the particular configured standard in use. It can be specified directly and often is used for complex equipment setups where it is calculated separately.

4.2 Single Runtime Readings

With VSET S1 set to zero, the repeat measurements calculation of variable U2 (A2LA 1 [Type A] and A2LA 8 [Type B]) can be set to A2LA 8 resolution and a previously determined standard deviation can be entered for single measurements.

Using VSET U3 through U10 DF1-DF10 and sensitivity in latest versions the other variables not found in MET/CAL[®] (but necessary for use) can be input.

4.3 Calibration of Standards/Uncertainties

The reference value is reported with a measurement and uncertainty (A2LA 5 [Type B]). These uncertainties need to be updated after each calibration; we suggest using U5 to store the standards' uncertainties.

These values could be typed into each and every procedure. However, we recommend storing this data external from the procedure in an asset or model specific .ini files, thereby making input less cumbersome for widely used equipment. Storing these values externally would allow users to update the data after each calibration without having to modify the procedure.

4.4 Environmental Variations

The use of U8 and U9, combined with operator queries and defaults to lab typical values, could be set up for lab and on-site work to account for environmental related uncertainties.

4.5 Our Mapping of the Uncertainty Contributors

Table 2. A2LA item A or B Type with corresponding MET/CAL variables.

Item	MET/CAL Variable
1A	S1 part of U2 [through repeat measurements - or use U10]
2A	U3 reproducibility [in dotini, or measurement code]
3A	U6 Stability drift (from charted values of standards) [in a .ini file or measurement code]
4A	U4 Other
5B	U5 reference value uncertainty [in a .ini file, user ACC file or measurement code]
6B	U1 Absolute spec for calibration interval [in ACC files]
7B	U7 resolution of Standards [in measurement code]
8B	S1 part of U2 resolution of UUT
9B	U8 U9 Environmental effects [in subprogram what environment default or enter]
10A/B	U10 standard deviation previously determined for run time nmeas=1 [in measurement code]

4.6 Reviewing the MFILE

Once you have all your uncertainty contributors added to your program, you can verify all the contributors are there by creating a comma separated file and viewing all the components in an Excel file. The following is a short sample program we used for this demonstration to show PFA:

```
1.001 ASK+      K
1.002 VSET      NMEAS = 1
1.003 VSET      MFILE = C:\METCAL\PROC\tester\TESTER.CSV
```

```

1.004 VSET      U10 = 0.1
1.005 VSET      U5 = .25
1.006 VSET      UUT_RES = .01
1.007 VSET      S1 = 0
1.008 ACC       100_units    1U
1.009 TOL       4.00U
1.010 MATH      MEM = 103.40
1.011 MEMC      100_units    TOL
2.001 ACC       100_units    1U
2.002 TOL       4.00U
2.003 MATH      MEM = 103.32
2.004 MEMC      100_units    TOL
3.001 ACC       100_units    1U
3.002 TOL       3U
3.003 MATH      MEM = 102.16
3.004 MEMC      100_units    TOL
4.001 ACC       100_units    1U
4.002 TOL       3U
4.003 MATH      MEM = 102.13
4.004 MEMC      100_units    TOL
5.001 ACC       100_units    1U
5.002 TOL       2U
5.003 MATH      MEM = 101.10
5.004 MEMC      100_units    TOL
6.001 ACC       100_units    1U
6.002 TOL       2U
6.003 MATH      MEM = 101.08
6.004 MEMC      100_units    TOL
7.001 ACC       100_units    1U
7.002 TOL       1.1U
7.003 MATH      MEM = 100.61
7.004 MEMC      100_units    TOL
8.001 ACC       100_units    1U
8.002 TOL       1.1U
8.003 MATH      MEM = 100.59
8.004 MEMC      100_units    TOL
9.001 END

```

The file created by line 1.003 VSET MFILE = C:\METCAL\PROC\tester\TESTER.CSV imported into MS Excel[®], with blank columns hidden, appears below (Figures 1 & 2):

	A	F	G	H	I	J	K	L	M
1	Step Number	UUT Indicated	System Actual	Expanded Uncertainty	Standard Uncertainty	Confidence	Coverage	F	System Accuracy
2	1.011	100	103.4	1.135796343	0.567898172	2	2		1
3	2.004	100	103.32	1.135796343	0.567898172	2	2		1
4	3.004	100	102.16	1.135796343	0.567898172	2	2		1
5	4.004	100	102.13	1.135796343	0.567898172	2	2		1
6	5.004	100	101.1	1.135796343	0.567898172	2	2		1
7	6.004	100	101.08	1.135796343	0.567898172	2	2		1
8	7.004	100	100.61	1.135796343	0.567898172	2	2		1
9	8.004	100	100.59	1.135796343	0.567898172	2	2		1
10									
11									
12									

Figure 1. Left side of the spreadsheet.

N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	BA	BC	BD
S1	S2	Standard Deviation	RSS	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	UUT Resolution	Number of Measurements	Value 1
0	0.002886751		0.567898172	0.5	0.002886751	0	0	0.25	0	0	0	0	0.1	0.01		103.4
0	0.002886751		0.567898172	0.5	0.002886751	0	0	0.25	0	0	0	0	0.1	0.01		103.32
0	0.002886751		0.567898172	0.5	0.002886751	0	0	0.25	0	0	0	0	0.1	0.01		102.16
0	0.002886751		0.567898172	0.5	0.002886751	0	0	0.25	0	0	0	0	0.1	0.01		102.13
0	0.002886751		0.567898172	0.5	0.002886751	0	0	0.25	0	0	0	0	0.1	0.01		101.1
0	0.002886751		0.567898172	0.5	0.002886751	0	0	0.25	0	0	0	0	0.1	0.01		101.08
0	0.002886751		0.567898172	0.5	0.002886751	0	0	0.25	0	0	0	0	0.1	0.01		100.61
0	0.002886751		0.567898172	0.5	0.002886751	0	0	0.25	0	0	0	0	0.1	0.01		100.59

Figure 2. Right side of the spreadsheet.

5.1 Guard Bands and Z540.3 Checks

MET/CAL[®] contains flexible guard banding commands, that when enabled, meet the requirements of Z540.3 PFA risk compliance using “Method 6: Guard Bands Based on Measurement Uncertainty” [4]. One major drawback to this implementation is that the guard banding must be enabled during the calibration. In certain business environments, the need to screen calibrations for risk compliance at the time of calibration is impractical. Post calibration analysis of risk compliance is more practical, and can be performed with the included reporting software package, thus eliminating the need to perform and calculate risk compliance at the time of calibration.

5.2 Z540.3 Method Six

Below, we demonstrate a method to highlight any measurements that may have a false accept risk incompatible with Z540.3 requirements without requiring guard bands in MET/CAL[®] be selected.

Using Crystal Reports[®], we create and insert a new formula field similar to the TUR formula included with MET/CAL[®]. We named it DOTTUR and the text below is an approximation to method six of the Z540.3 handbook. It could be refined to the precision needed by an organization in actual implementation.

```
WhileReadingRecords;
Global numberVar dotTUR;
//dotTUR := 2/1.96 // ToNumber({Ver_7_Certificates.tur})// * (2/1.96)
```

```
// Check for Number present in TUR field
If NumericText ({Ver_7_Certificates.tur})
// If present then
```



```

Then If ToNumber ({Ver_7_Certificates.tur}) <= 4
  then if ToNumber ({Ver_7_Certificates.tur}) <= 2 and ToNumber
({Ver_7_Certificates.tol_err}) >= 55
    // Then Print it
    Then "PFA>"
    // Else print null string
    Else If ToNumber ({Ver_7_Certificates.tur}) <= 3 and ToNumber
({Ver_7_Certificates.tol_err}) >= 72
    // Then Print it
    Then "PFA>"
    // Else print null string
    Else If ToNumber ({Ver_7_Certificates.tur}) <= 4 and ToNumber
({Ver_7_Certificates.tol_err}) >= 84
    // Then Print it
    Then ">PFA"
    // Else print null string
    Else ""
Else ""
Else ""

```

We then select the formula and drag it into our report. The example program (4.6 above) will generate some values that will satisfy the formula and print the >PFA text on the report. Using our report format the results file appears as (Figure 3):

Test Results								
<u>Test Description</u>	<u>True Value</u>	<u>Test Result</u>	<u>Units</u>	<u>Lower Limit</u>	<u>Upper Limit</u>	<u>Exp Uncert</u>		<u>TAR</u>
100 units		103.400	_units	96.000	104.000	1.1e+000	_units	>PFA 4.00
100 units		103.320	_units	96.000	104.000	1.1e+000	_units	4.00
100 units		102.160	_units	97.000	103.000	1.1e+000	_units	PFA> 3.00
100 units		102.130	_units	97.000	103.000	1.1e+000	_units	3.00
100 units		101.100	_units	98.000	102.000	1.1e+000	_units	PFA> 2.00
100 units		101.080	_units	98.000	102.000	1.1e+000	_units	2.00
100 units		100.610	_units	98.900	101.100	1.1e+000	_units	PFA> 1.10
100 units		100.590	_units	98.900	101.100	1.1e+000	_units	1.10
***** End of Report *****								

Figure 3. Report format.

6. Download the Example

The example procedure demonstrated in our presentation for calibrating high volt equipment, complete with full uncertainty calculations, is available for download and review:

http://www.CalLabSolutions.com/Downloads/A2LA_Sample_Unc_Budget.Zip

7. Summary

A2LA's new requirements for uncertainty budgets and the 2% false except requirements in Z540.3 may require labs to make modifications to their existing automated test systems. For many labs, their existing software system may already have a mechanism to support these new requirements, they just have to be properly enabled. Though this paper does not detail all the specifics for every metrology discipline, it can serve as a guide for developers writing MET/CAL[®] procedures and auditors inspecting calibration labs.

8. References

1. P. Wright, "Consensus on the minimum contributors for electrical and microwave/rf uncertainty budgets," *A2LA today*, no. 103, pp. 11-12, June 2009.
2. N. Mason, "Software strategies for on-site calibration", Measurement Science Conference: 1999 Workshop and Symposium.
3. Fluke Corporation, *MET/CAL V7.2 Metrology Software Reference Manual*, rev. 8, pp. xx-xx, November 2006.
4. D. Deaver, J. Somppi, "A study of and recommendations for applying the false acceptance decision risk specification of Z540.3," Measurement Science Conference: 2010 Workshop and Symposium.